Kentucky
Agricultural Experiment Station
University of Kentucky

CALCIUM METABOLISM IN THE LAYING HEN

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1. Effect of minerals on the production of eggs and on their composition.
2. Effect of minerals on the composition of the bones and carcass.
3. Behavior of grit in the gizzard.
4. Tabulated data.

BULLETIN NO. 250

(Research Bulletin)

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SUMMARY

1. Calcium in rock phosphate (tricalcium phosphate) can be utilized by the hen for the growth of bone but not in the formation of eggshell.

2. In the absence of sufficient calcium carbonate, fewer eggs are produced than where the supply of available calcium is adequate.

3. In the absence of sufficient calcium carbonate, the eggshells become progressively thinner; the percentage composition of the shells, however, remains constant.

4. Deficiency of calcium apparently has little or no influence on the weight of the liquid part of the egg, under the conditions of this experiment, nor upon the percentages of calcium, magnesium and phosphorous in the liquid part.

5. Deficiency of calcium retards development of bone.

6. Crushed limestone of good quality (nonmagnesian) and crushed oyster shells serve equally well as sources of calcium for laying hens.

7. Deficiency of calcium in the diet of the hen is not the primary cause of the production of shell-less (soft shell) eggs.

8. Calcium in calcium carbonate can be utilized by the hen in the formation of both eggshell and bone.

9. The absence of grit from the diet of hens in confinement during the first eight months of their laying period does not affect their egg production nor their physical condition.

10. The growth of bone in the lot which received rock phosphate (tricalcium phosphate) was greater than that in the lots which received limestone and oyster shell (calcium carbonate).

11. Limestone, oyster shell and rock phosphate do not function permanently as grinders.

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BULLETIN NO. 250

(Research Bulletin)

Calcium Metabolism in the Laying Hen

By G. D. BUCKNER, J. HOLMES MARTIN and A. M. PETER*

It is well known that calcium and phosphorous are of the greatest importance in building the skeleton of growing fowls and that calcium is essential for the formation of egg shells, which are composed almost entirely of calcium carbonate. Chemical analyses of the grains commonly fed to poultry show that they contain relatively less calcium than phosphorus, which suggests that grains alone do not supply enough calcium.

The improvement of domestic fowls has increased their egg-laying power greatly. Some hens have laid 300 eggs or more in a year and, inasmuch as the normal egg shell contains about 2.4 grams of calcium oxide, this implies a calcium requirement of about 720 grams of calcium oxid annually, or nearly 1,300 grams of calcium carbonate, for the production of the shells, under maximum egg production.

Common experience teaches that calcium in some concentrated form, such as oyster shells or ground limestone, must be given to poultry, in addition to the ordinary feeds, in order to supply the large amount of calcium necessary for maximum egg production and for their general welfare. It is customary, likewise, to give fowls a siliceous grit, usually crushed granite, its principal function being to aid and hasten digestion by helping the grinding process in the gizzard.

In 1920, Buckner and Martin[1] published the results of some experiments conducted at this station, from which they con-

*Due credit is given by the authors to Mr. W. C. Pierce, formerly Assistant Chemist, for a large share in the chemical work reported in the bulletin.

[1] Buckner, G. D., and Martin, J. H., Jour. Biol. Chem., Vol. XLI, No. 2, Feb., 1920, p. 195.

cluded that, during calcium starvation, hens continue laying eggs until there is a general depletion of calcium, magnesium and phosphorus in their bones and thinning of the egg shells, followed by a cessation of egg laying. They further showed that the percentages of calcium, magnesium and phosphorus in the contents of the egg remained constant during calcium starvation and that no shell-less eggs were laid under this restriction.

Wheeler,[2] also, has published some interesting results showing a thinning of the egg shells following a long continuance of a diet low in calcium, and that calcium is removed freely from the bones for shell formation.

Riddle and Hanke,[3] find that the percentage of inorganic matter in dry shells remains unchanged under extra feeding of calcium salts and state that "the production of inadequate shells . . . is probably not caused by deficient calcium supply in the foods," and that the feeding of organic calcium salts to female ring-doves failed appreciably to strengthen their egg shells.

THE EXPERIMENT

In order to verify the results of the experiments concerning the metabolism of laying hens as affected by inorganic materials, previously made at this Station, and to throw further light on the subject, six lots, each containing ten seven-months-old White Leghorn pullets which came from the same parent stock, hatched in an incubator the same day and raised under identical conditions, were fed a uniform diet of dry mash and grain, supplemented by mineral substances as follows:

Lot 1—No mineral matter.

Lot 2—Granite grit, *ad libitum.*

Lot 3—Granite grit and oyster shell, *ad libitum.*

Lot 4—Granite grit and limestone, *ad libitum.*

Lot 5—Limestone, *ad libitum.*

Lot 6—Rock phosphate, *ad libitum.*

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[2] Wheeler, W. P., Bull. N. Y. Agri. Expt. Sta. (Geneva), 1919, No. 468.

[3] Riddle, O., and Hanke, M. C. E., Am. Jour. Physiol., Vol. LVII, No. 2, Sept., 1921, p. 264.

The dry mash consisted of corn meal 6 parts, bran 3, middlings 3, ground oats 3, tankage 5 and charcoal 1, and was before the hens at all times.

The grain mixture, which consisted of cracked corn 2 parts and oats 1 part, was fed twice a day, in the morning and evening, by scattering it in the straw on the floor.

The mineral substances were accessible to the hens of the appropriate pens at all times, in hoppers. The grit and oyster shell were the commercial materials such as are commonly used by poultrymen, the former being a gray granite. The limestone had been crushed to about ¼-inch size, and the dust removed by running it over a fine screen. It was obtained from a commercial crusher near Lexington, using the Trenton limestone of this vicinity. The rock phosphate was from the workings at Wallace's Station in Woodford county, Ky., and had been prepared by crushing to about ¼-inch size and washing out the fine dust. This stone is somewhat softer than the limestone and quite porous.

Analyses of the Feeds—Analyses made of the feeds and of the mineral supplements used are given in Table 1. The mineral substances were analyzed by digestion in strong hydrochloric acid and determination by the usual methods.

Table 1—Analyses of Feeds and Mineral Supplements, in percentage of the Material as Fed

Material	Crude ash	Calcium oxid (CaO)	Magnesium oxid (MgO)	Phosphorus pentoxid (P_2O_5)	Excess CaO after combining P_2O_5 with Mg and Ca*
Grain	2.05	.09	.12	.74	Deficit 0.56
Mash	8.02	1.81	.30	2.91	Deficit 1.96
Straw (litter)	3.89	.28	.09	.45	0
Grit		2.42	1.10	.02	2.42
Oyster shell		54.33	.18	.07	54.33
Limestone		49.14	1.78	.01	49.14
Rock phosphate		50.72	1.36	36.50	9.92

*As tribasic phosphates.

The figures in the last column show that the grain and mash do not contain enough calcium to form tricalcium phosphate with the phosphorous present. The rock phosphate contains an excess of calcium, part of which is in the form of carbonate and part in the form of fluorid. Boiling a finely ground portion with solution of ammonium chlorid dissolved calcium equivalent to 1.25 per cent of calcium carbonate. Similar treatment of the tankage used in the mash dissolved the equivalent of nearly 3 per cent of calcium carbonate, and a qualitative test showed the presence of carbonate in the tankage.

This experiment started December 1, 1920, and ended July 31, 1921. During these eight months the pullets were confined in a house with a concrete floor and at no time allowed access to the ground, thereby excluding any chance of their getting materials containing calcium, magnesium or phosphorus other than those supplied. No milk or green foods were fed during the experiment.

The presentation and discussion of results has been divided into four parts; the first deals with the effect of the inorganic supplements on the number of eggs laid and the composition of the egg shells and their contents; the second deals with the effect of these factors on the composition of the bones and carcasses of the hens; the third deals with the behavior of grit in the gizzards of the hens and the quantity of inorganic materials consumed, and the fourth part contains tabulations of original data obtained in the experiment. Occasional reference to these tables will be made in the discussion.

Part I.

EFFECT OF MINERALS ON THE PRODUCTION OF EGGS AND ON THEIR COMPOSITION

A trap-nest record was kept of each hen. Eggs laid on the floor were included in the total counts but were not analyzed.

Table 2 gives a summary of the average egg production, change in weight of the hens, and mortality. In computing the average number of eggs per hen, hens that died during the experiment were given credit in proportion to the time they lived,

and hens that did not lay more than five eggs were excluded from the average.

Several common diseases of poultry appeared in all pens and the death rate was high in all lots but not uniform in the several lots. However, it did not seem to be correlated with the kind of minerals received by the several lots.

All the hens that received rock phosphate were slightly affected with diarrhoea, a condition which was not prevalent in the other lots. This may have been caused by the phosphate and may have had much to do with the low egg production of this lot, the lowest of all.

All lots gained weight in December and all lots except No. 6 were heavier on December 31 than at the end of the experiment.

Table 2—Average Egg Production, Mortality and Gain in Weight

Lot number	1	2	3	4	5	6
Minerals fed	None	Grit	Grit and oyster shell	Grit and lime-stone	Lime-stone	Rock phos-phate
Eggs per hen	34.5	39.7	53.2	56.6	61.8	21.6
Number of deaths	8.	4.	6.	3.	6.	5.
Gain in weight of the sur-vivors, per cent	19.	26.	—3.	9.	20.	21.

The lot which received no mineral matter in addition to the grain and mash fed, laid 34.5 eggs per hen in eight months, or nearly 60 per cent more than the number laid by the lot that received rock phosphate. This indicates that the calcium in rock phosphate cannot be utilized by the hen in the production of eggs, calcium being the limiting factor in the case under consideration, but the result may have been influenced by the detrimental effect which the phosphate seems to have had upon the health of the hens.

The lot which received grit alone laid 5 eggs per hen more than that which received no mineral supplement, or 15 per cent more. The presence of a small proportion of available calcium (2.42% CaO dissolved by HCl) in the granite grit consumed

by these hens may have contributed to this result. Inasmuch as an egg contains about 2.5 grams of CaO, 5 eggs require for their formation about 12.5 grams of CaO. This amount could be supplied by 517 grams, or about a pound of grit if the 2.42 per cent found by analysis is wholly available. A lower availability is offset by the consideration that the hens of this pen actually took from the hopper 10.2 lbs. of grit per hen, in 8 months (Table 13, Part III). The hens in all pens developed an abnormal appetite for the mineral supplement.

The average number of eggs laid during the 8 months by the lots which received oyster shell and limestone, with or without grit, were quite similar, indicating that limestone and oyster shell serve the same purpose as sources of calcium and to the same extent, and that the grit consumed by the hens of lots 3 and 4 did not increase their production of eggs. Indeed, the fact that the lot which received limestone but no grit produced five eggs more per hen, in 8 months, than the lot which had free access to both limestone and grit shows that the absence of grit from the diet of laying hens, under the conditions of this experiment, does not decrease the production of eggs. The lot which received limestone alone, however, used almost twice as much limestone per hen as the lot which received both limestone and grit.

Analyses of the Eggs—The first three eggs laid each month by each hen, or as many as she laid, if fewer than three, were analyzed for calcium, magnesium and phosphorus, using the composite samples of the shells and contents which had been carefuly separated. The shell membranes were not removed but were analyzed with the shells, a somewhat different procedure from that followed in the previous experiment. Inasmuch as the quantities of calcium, magnesium and phosphorus contained in the small quantity of the white adhering to the shells after careful draining may be considered negligible, this was left with the shell. The shells were dried at 100° C. for 24 hours, weighed after cooling and burned until white. The determinations of CO_2-free ash, calcium, magnesium and phosphorus were made with this dry material, after grinding and mixing.

Considerable difficulty was experienced in ashing the egg contents and after many experiments it was found that the best results, accuracy and speed being considered, were obtained by placing the liquid contents of the eggs composing the sample in a porcelain evaporating dish and thoroly mixing with 5 cc. per egg of a hot solution of sodium carbonate (80 grams of calcium-free Na_2CO_3 dissolved in hot distilled water to 200 cc.). The mass was then dried at 120° C. and ashed in a platinum dish, a small quantity being placed in the dish at a time. The residue obtained in this manner was easily brought into solution with hot water and hydrochloric acid. The solution was made to 100 cc. and an aliquot taken for the determination of calcium and magnesium according to the method of McCrudden,[4] while phosphorus was determined in another portion by the volumetric method of the Association of Official Agricultural Chemists.[5]

The findings are summarized in Tables 3 to 8, which contain averages for the entire experiment. The results in more detail are given in Part IV.

Table 3—Average Weights of the Contents and of the Mineral Substances Contained Therein, Expressed as Grams per Egg, for 8 Months

	Lot 1 No Mineral Supplement	Lot 2 Grit	Lot 3 Grit Shell	Lot 4 Grit Limestone	Lot 5 Limestone	Lot 6 Rock Phosphate
Contents	41.19	43.26	42.70	44.28	43.47	40.80
Calcium oxid, CaO	0.028	0.031	0.032	0.034	0.032	0.032
Magnesium oxid, MgO	0.009	0.009	0.009	0.010	0.009	0.010
Phosphorus pentoxid, P_2O_5	0.182	0.204	0.213	0.217	0.215	0.196

Table 4—Average Percentages of Mineral Substances in the Contents, for 8 Months

	Lot 1 No Mineral Supplement	Lot 2 Grit	Lot 3 Grit Shell	Lot 4 Grit Limestone	Lot 5 Limestone	Lot 6 Rock Phosphate
Calcium oxid, CaO	0.068	0.072	0.075	0.077	0.074	0.078
Magnesium oxid, MgO	0.022	0.021	0.021	0.023	0.021	0.025
Phosphorus pentoxid, P_2O_5	0.44	0.47	0.50	0.49	0.50	0.48

[4] McCrudden, F. H., Jour. Biol. Chem., 1909-10, Vol. VII, p. 83.
[5] Methods of Analysis, A. O. A. C. Revised to Nov. 1, 1919, p. 3.

Table 5—Average Weights of CO_2-free Shell Ash and Mineral Contents Thereof, Expressed as Grams per Egg, for 8 Months

	Lot 1 No Mineral Supplement	Lot 2 Grit	Lot 3 Grit Shell	Lot 4 Grit Limestone	Lot 5 Limestone	Lot 6 Rock Phosphate
Shell ash	1.93	1.99	2.49	2.46	2.60	1.81
Calcium oxid, CaO	1.878	1.937	2.433	2.403	2.540	1.774
Magnesium oxid, MgO	0.023	0.029	0.032	0.034	0.035	0.028
Phosphorus pentoxid, P_2O_5	0.014	0.013	0.014	0.015	0.016	0.008

Table 6—Average Percentages of Mineral Substances in the CO_2-free Shell Ash for 8 Months

	Lot 1 No Mineral Supplement	Lot 2 Grit	Lot 3 Grit Shell	Lot 4 Grit Limestone	Lot 5 Limestone	Lot 6 Rock Phosphate
Calcium oxid, CaO	97.31	97.34	97.70	97.69	97.70	98.00
Magnesium oxid, MgO	1.45	1.46	1.28	1.38	1.35	1.55
Phosphorus pentoxid, P_2O_5	0.73	0.65	0.56	0.61	0.62	0.44

Table 7—Average Weights and Mineral Content of the Whole Egg, for 8 Months, Expressed in Grams

	Lot 1 No Mineral Supplement	Lot 2 Grit	Lot 3 Grit Shell	Lot 4 Grit Limestone	Lot 5 Limestone	Lot 6 Rock Phosphate
Whole egg	45.88	47.94	48.46	49.76	49.20	45.16
Calcium oxid, CaO	1.906	1.968	2.464	2.443	2.573	1.806
Magnesium oxid, MgO	0.037	0.039	0.041	0.043	0.044	0.038
Phosphorus pentoxid, P_2O_5	0.193	0.216	0.227	0.232	0.230	0.204

Table 8—Average Percentages of Mineral Substances in the Whole Egg, for 8 Months

	Lot 1 No Mineral Supplement	Lot 2 Grit	Lot 3 Grit Shell	Lot 4 Grit Limestone	Lot 5 Limestone	Lot 6 Rock Phosphate
Calcium oxid, CaO	4.15	4.11	5.08	4.92	5.23	4.00
Magnesium oxid, MgO	0.081	0.081	0.085	0.086	0.089	0.084
Phosphorus pentoxid, P_2O_5	0.42	0.45	0.47	0.47	0.47	0.45

The average weights of the egg contents for 8 months of lots 1 and 6 are appreciably less than those of lots 2, 3, 4 and 5. This seems to be accidental and may not be connected with the inorganic intake of the hens, since the range of variation is considerable in all lots, and if the lack of calcium was the cause of smaller contents, lot 2, which received grit alone, would have been considerably smaller than lots 3, 4 and 5, which received calcareous supplements. In the lots which received calcium carbonate a slight increase in the weight of the egg contents from month to month is noticeable in the first four or five months which is not apparent in lots 1 and 6, but the increase is not maintained to the end.

The average number of grams and the percentages of CaO, MgO and P_2O_5 in the contents of the eggs laid by the several lots varied only slightly during the 8 months, showing that the intake of calcium, magnesium and phosphorus in the minerals supplied has practically no influence on the content of these elements in the liquid part of the eggs. (See Part IV, Tables 16 to 22.)

Table 5 shows that the average weight of CO_2-free ash in the egg shells per lot for 8 months, is appreciably less in lots 1, 2 and 6 than in lots 3, 4 and 5. In lots 1 and 2 there is a gradual thinning of the shells of the eggs as compared with those of lots 3, 4 and 5. The average weights of CaO in the CO_2-free ash of these lots ran parallel with the CO_2-free ash, since the percentages were practically constant.

The average monthly weights and percentages of MgO and P_2O_5 in the shells are reasonably constant, since the variation in the six lots is about the same as is the monthly variation of each lot. (See Part IV, Tables 24 to 29.)

Table 7 shows that the average weight of the egg is less in lots 1 and 6 than in the other lots. The average weight of CaO is distinctly larger in lots 3, 4 and 5 than in the other lots, and is least in lot 1, which received no minerals, whereas the quantities and percentages of MgO and P_2O_5 in the whole eggs vary but little in the six lots, tho they are a little larger in lots 3, 4 and 5 than in the others.

During this experiment no shell-less (soft shelled) eggs were laid in any of the six lots.

Some of the hens in each lot were slightly affected with vent gleet, chickenpox and other diseases. The analyses of the eggs from the hens thus affected show no significant variation in composition from the normal.

Part II.

EFFECT OF MINERALS ON THE COMPOSITION OF THE BONES AND CARCASS

At the beginning of the experiment, December 1, 1920, two representative hens from the same hatching as those used in the experiment were killed and their femurs and tibias dissected out and, after separately weighing, the CO_2-free ash and the CaO, MgO and P_2O_5 contained therein were determined. On August 1, 1921, another hen of the same lot, which received the same treatment as those in the experiment up to December 1, 1920, but which, from that time until August 1, 1921, had been allowed the normal freedom of a meadow and been fed the same as lot 3, was killed and similarly dissected as were the early controls just mentioned. All hens remaining in the six lots at the close of the experiment were killed and treated individually in the same way.

Analyses of the Leg Bones—The results in Table 9 show that the average total weight of the 4 large leg bones was approximately the same in the six lots, whereas that of the first controls was less, these hens being 8 months younger than the others. The weight of the leg bones in the second control exceeded any of the averages, tho equaled or exceeded by three or four individuals in the experiment. This may be an individual variation or because conditions were more favorable for growth with the hen running at large than with those confined in the house.

The average weights of the CO_2-free ash of the leg bones from lots 1 and 2 were less than those from lots 3, 4, 5 and 6, which received the concentrated calcium materials, and the ash

from lot 6, which received rock phosphate, was heavier than that from any of the other lots, tho less than the ash from the second control. This agrees with the results published by D'Auchald,[6] in 1904, who obtained a heavier skeleton by adding daily 4 grams of powdered bone per hen to an ordinary poultry feed.

The average weights of CaO in the leg bones of the hens of lots 1 and 2 are appreciably less than those of the other lots and the average weight for lot 6 is the greatest of any except the second control. The average percentages of CaO in the ash of the leg bones of all lots, Table 10, are approximately the same, tho a little less in lots 1 and 2 than in the others.

The average weights of MgO in the leg bones of lots 1 and 2 are somewhat less than in the other lots, while the percentage in the ash is reasonably constant for all lots.

The average weights of P_2O_5 in the leg bones of lots 1 and 2 are less than those of the other four lots, but the percentage in the ash varies between narrow limits.

It would seem that in calcium starvation as exemplified in the pullets of lots 1 and 2, a smaller amount of ash, CaO, MgO and P_2O_5 is deposited in the leg bones than is deposited when the supply of calcium is adequate, but the percentage composition of the bones varies very little. The percentage of calcium oxid in the ash, however, is consistently, tho slightly, larger in the lots which received calcareous supplements than in lots 1 and 2 and the first controls, as is, also, the excess of CaO remaining after combining the P_2O_5 with MgO and CaO as tribasic phosphates, indicating that more calcium carbonate was deposited in the bones of the hens receiving calcareous materials than was the case in the absence of the calcareous supplement. These relations appeared more strikingly in the experiment of 1918-19 than in the present one.[7]

The average weights of CaO and P_2O_5 in the leg bones of the hens of lot 6 are somewhat larger than those of the other lots, except the second control. This would indicate that a larger growth of bone is caused by the addition of tricalcium phosphate

[6] D'Auchald, H., J. Ag'e Prat., 1904, VII, 619.
[7] Buckner, G. D. and Martin, J. H., loc. cit.

to the ration than by the addition of calcium carbonate; however, the difference in this case may have been caused by the greater egg production of lots 3, 4 and 5, which laid many more eggs than did lot 6, thereby, perhaps, diverting calcium from the production of bone to the production of eggs. This further indicates that the calcium in tricalcium phosphate is available for the growth of bones but cannot be utilized in the formation of egg shells.

Table 9—Average Weights of 4 Leg Bones and of Mineral Substances Contained Therein, Expressed in Grams

Date	Lot	Wt. of 4 Leg Bones		CO_2-free Ash	Calcium Oxid, CaO	Magnesium Oxid, MgO	Phosphorus Pentoxid, P_2O_5	No. of Hens in the Average
		Fresh	Dried at 120° C.					
Dec. 1, 1920	1st controls	22.34	13.85	5.13	3.090	0.075	2.341	2
Aug. 1, 1921	1. No minerals	30.36	16.77	7.97	4.332	0.098	3.274	3
do	2. Grit	31.95	19.09	8.80	4.793	0.104	3.582	6
do	3. Grit, shell	31.30	21.07	10.59	5.789	0.125	4.288	3
do	4. Grit, limestone	30.73	21.26	10.18	5.612	0.123	4.172	5
do	5. Limestone	30.54	19.86	10.69	5.885	0.123	4.365	4
do	6. Rock phosphate	33.12	21.15	11.20	6.165	0.137	4.542	5
do	2nd control	36.98	23.30	11.94	6.557	0.143	4.880	1

Table 10—Average Percentages of Ash in the Leg Bones, and of Mineral Substances in the Ash

Date	Lot	Percentage of CO_2-free Ash in the Leg Bones		Percentage in the CO_2-free Ash of the Leg Bones				
		Fresh	Dried at 120° C.	Calcium Oxid, CaO	Magnesium Oxid, MgO	Phosphorus Pentoxid, P_2O_5	Total	Excess, CaC
Dec. 1, 1920	1st controls	25.24	40.84	54.88	1.34	41.58	97.80	7.53
Aug. 1, 1921	1. No minerals	26.35	47.78	54.33	1.23	41.08	96.64	7.41
do	2. Grit	27.57	46.10	54.44	1.18	40.70	96.32	7.90
do	3. Grit, shell	33.81	50.17	54.68	1.18	40.49	96.35	8.39
do	4. Grit, limestone	32.50	47.82	55.21	1.19	41.04	97.44	9.29
do	5. Limestone	34.66	53.48	55.02	1.15	40.87	97.04	8.24
do	6. Rock phosphate	33.64	53.01	55.02	1.21	40.56	96.79	8.69
do	2nd control	32.29	51.24	54.92	1.20	40.87	96.99	8.21

Analyses of the Carcasses—At the time the leg bones were dissected out, the head, skin, feathers, feet and intestines, with the contents and the lining of the gizzard, were removed and discarded to eliminate any extraneous matter which might vitiate the comparative analyses. The remaining carcass, including all the flesh and bones of the body and neck and the flesh of the legs, was carefully ashed and analyzed, in the same manner as the leg bones.

Tables 11 and 12 contain a synopsis of the results.

Table 11—Average Weights of the Hens, of the Carcasses as Analyzed,* and of the Mineral Matter in the Carcass, Expressed as Grams

Date	Lot	Hens as Received	Carcasses as Analyzed	CO_2-free Ash of Carcasses	Calcium Oxid, CaO	Magnesium Oxid, MgO	Phosphorus Pentoxid, P_2O_5	No. of Hens in the Average
Dec. 1, 1920	1st controls	840	485	16.75	7.043	0.334	7.301	2
Aug. 1, 1921	1. No minerals	1203	694	23.62	10.031	0.441	10.350	3
do	2. Grit	1392	844	25.58	10.668	0.443	10.975	6
do	3. Grit, shell	1212	758	27.60	12.815	0.436	11.389	3
do	4. Grit, limestone	1321	804	27.32	12 473	0.466	11.736	5
do	5. Limestone	1138	717	26.16	12.184	0.422	11.091	4
do	6. Rock phosphate	1380	840	28.93	13.466	0.473	12.283	5
do	2nd control	1490	963	28.17	12.246	0.507	12.127	1

Table 12—Average Percentages of Ash in the Carcasses and of Mineral Substances in the Ash, and Oxygen ratio

Date	Lot	CO_2-free Ash	Percentages in the CO_2-free Ash			O of P_2O_5 / O of CaO+MgO
			Calcium Oxid, CaO	Magnesium Oxid, MgO	Phosphorus Pentoxid, P_2O_5	
Dec. 1, 1920	1st controls	3.45	41.98	1.99	43.58	1.92
Aug. 1, 1921	1. No minerals	3.41	42.48	1.87	43.84	1.92
do	2. Grit	3.07	41.70	1.73	42.93	1.92
do	3. Grit, shell	3.69	44.37	1.58	41.42	1.75
do	4. Grit, limestone	3.41	45.05	1.62	42.79	1.78
do	5. Limestone	3.69	46.62	1.62	42.35	1.71
do	6. Rock phosphate	3.43	46.41	1.64	42.57	1.72
do	2nd control	2.93	43.47	1.80	43.05	1.86

*See preceding paragraph.

Apparently calcium starvation did not influence the average total weights of the pullets in lots 1 and 2, nor did it influence very greatly the quantity of CO_2-free ash in them, tho lots 1 and 2 have distinctly less ash than the lots which received calcareous supplements. The comparatively small quantity of ash in the hens of lot 5 may have been due to the larger number of eggs laid by them.

The average number of grams of CaO and P_2O_5 in the carcasses is less in lots 1 and 2 than in the remaining lots, while the quantity of MgO seems to be about the same in all lots, tho largest in the second control.

The percentage of MgO varies but little in all lots. The percentage of CaO is less in lots 1 and 2 than in the others, a further indication that in calcium starvation a smaller amount of calcium and phosphorus is deposited in the body of laying hens than would occur in the presence of an abundance of calcium carbonate.

The percentage of phosphorus pentoxid is somewhat less in the lots which received calcareous supplements than in those which did not, and the oxygen ratio approaches that of tricalcium phosphate (1:1.67) more nearly in the former than in the latter.

Part III.

BEHAVIOR OF GRIT IN THE GIZZARD

It is generally accepted as a fact that the chief function of grit is to aid the gizzard in crushing and grinding the food and it is held by some poultry experts that grit is essential to the well-being of poultry. In another paper,[8] the subject of the function of grit in the gizzard of the chicken has been discust at length.

At the beginning of this experiment, when the first controls were killed for analysis, the contents of their gizzards were separated and all mineral particles the size of sand and larger,

[8] Buckner, G. D., and Martin, J. H., Poultry Science, April-May, 1922.

were carefully separated from the food and washed, dried, weighed and examined. On August 1, 1921, when the experiment ended, the contents of the gizzards of the hens remaining in the six lots and of the second control hen were similarly treated.

To determine if the limestone and rock phosphate contained any material which might function as grit, 50 grams of each, just as fed, were treated with hydrochloric acid and the residues washed with water by decantation. The limestone yielded 1.37 per cent of siliceous material, and the rock phosphate 0.82 per cent. From each of these residues six pieces of cherty material were selected which seemed large enough to serve as grit in the gizzard. In weight they corresponded to 0.84 per cent and 0.65 per cent, respectively, of the original stone. The rest of the insoluble matter was sand, fragments of siliceous fossils and a little pyrite. The oyster shell was not tested.

Table 13—Weights of Grit in Gizzards of Hens When Killed and of the Mineral Material Consumed per Hen by Each Lot in 8 Months

Date	Lot No.	Hen No.	Grit in the Gizzard		Mineral Materials Consumed in 8 Months*			
			From Each Hen	Average Per hen	Grit	Osyter-shell	Lime-stone	Rock Phos-phate
			Gms.	Gms.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 1, 1920	1st controls	A	16.20	18.4	.....	.....	.....	.....
		B	20.60					
Aug. 1, 1921	2nd control	C	23.00	23.0	.....	.....	.....	.....
Aug. 1, 1921	1	5	13.51					
"	No minerals	6	10.30	12.4	0	0	0	0
"		7	10.87					
"		8	15.10					
"	2	2	11.83					
"		3	21.97					
"	Grit	4	15.03	14.3	10.2	0	0	0
"		5	8.69					
"		7	14.20					
"		9	13.79					
"	3	1	11.15					
"	Grit, shell	8	11.05	9.7	6.4	6.5	0	0
"		9	6.92					
"	4	1	11.44					
"		5	12.90					
"	Grit, limestone	6	12.64	12.1	3.3	0	2.9	0
"		7	13.59					
"		8	11.63					
"		10	10.34					
"	5	1	3.70					
"	Limestone	5	4.50	4.4	0	0	4.5	0
"		7	6.31					
"		10	2.92					
"	6	1	4.70					
"		3	3.83					
"	Rock phosphate	5	6.21	5.3	0	0	0	4.0
"		6	5.30					
"		7	6.31					

*The figures represent the quantities of the different materials taken from the hoppers by the hens; an undetermined part of this was not swallowed, but dropt upon the floor.

Table 13 shows the actual number of grams of grit recovered from the gizzard of each hen, with the average for each lot and the weight per hen of the mineral materials taken from the

hoppers by each lot during eight months. We cannot say exactly how much of the latter was swallowed by the hens, because it was not possible to keep account of pieces of mineral dropt on the floor after having been picked from the hoppers.

The first controls had an average of 18.4 grams of grit in their gizzards and lots 1, 2, 3 and 4 had nearly as much, whereas lots 5 and 6 had only about one-fourth as much as the controls. The last control, which had been hatched at the same time as the hens in the experiment but had been allowed the run of a pasture and free access to grit and oyster shell, had 23 grams of grit in its gizzard, considerably more than any other hen except No. 3 in lot 2, which had about 22 grams. That this may have been an exceptionally large amount is suggested by the observation that 4 grams of it consisted of pieces of glass, perhaps picked up because of their bright appearance.

The grit in the gizzards of the hens of lots 2, 3 and 4 was mainly light-colored granitic material, evidently derived from the granite grit to which these hens had access, but included some of the other substances observed in lots 1, 5 and 6. Only a few pieces of shell in lot 3 and limestone in lot 4 were found. The material from lot 1 included siliceous gravel, chert, granitic material, anthracite, glass and one steel thumb-tack. The materials from lots 5 and 6 and from the controls were similar in character. Only a few pieces of limestone were found in lot 5 and of rock phosphate in lot 6. Assuming that the hens started with an average of about 18 grams of grit, as shown by the first two controls, those of lot 1 retained about 70 per cent of the original grit, since they received none during the experiment. This shows that a hen will retain the quantity of grit necessary for the purpose it serves and it appears to be as effective as new grit, at least for the time covered by this experiment. The 30 per cent loss, or part of it, may have been caused by the wearing away of the grit.

In lot 2 the hens which were given free access to grit had only 80 per cent of the quantity of grit assumed to be in their gizzards at the beginning of the experiment. The character of the grit in the hens of lot 2, however, was distinctly different

from that in lot 1, granitic material having taken the place of quartz gravel, chert and other materials which were prominent in lots 1, 5 and 6. It is remarkable that the quantity retained by the hens in this pen is only slightly more than that remaining in the no-grit hens. Only one of the six hens in this pen had more grit in her gizzard than the first two controls and she did not have as much as the last control. Considering the large quantity of grit handled by the hens of this pen, the suggestion is that the character of the grit may not have been attractive to them and they may have rejected some on that account, after having picked it from the hopper. The presence of glass in the gizzard of control C, and the predominance of white and light-colored gravel in the gizzards of all the controls suggests that the gray granite supplied to the hens in pens 2, 3 and 4 may not have been the kind most attractive to them. It should be stated, however, that only very little grit was seen on the floor about the hoppers at any time.

Lots 3 and 4, which received the grit and oyster shell or limestone, respectively, retained about the same quantity of grit as lot 1. One explanation of this is that during the experiment oyster shell and limestone would reach the gizzard in solid form and the hen not being able to distinguish between grit and the soluble or soft material, would pass both out regardless of selection, so that only an average quantity of grit was retained. .

In lots 5 and 6, which received no grit, the hens retained about one-fourth the quantity of grit which they are supposed to have had at the beginning of the experiment. Pieces of limestone and phosphate rock should become dissolved or disintegrated rather rapidly in the gizzard, both because they are softer than the grit and because the liquid present is acid. This view is substantiated by the observation that only very little limestone, oystershell and phosphate rock could be found in the gizzards of the hens that received these materials. If, however, the gizzard should become overcharged with pieces of limestone or of phosphate rock, in addition to the grit already present, as

night happen from the ingestion of too much of these materials at one time, it is conceivable that the excess might be allowed to escape, limestone fragments and pieces of grit passing out together indiscriminately, before the former have become softened or pulverized. Action of this kind would account for the small quantity of grit remaining in the gizzards of the hens of lots 5 and 6.

The control hen killed August 1, 1921, had 23 grams of grit in its gizzard. This larger quantity may be explained by the fact that this hen was eight months older and the gizzard larger, as contrasted with the hens that were examined December 1, 1920. She also lived on a sod range and in the natural process of obtaining food would be apt to gather grit and pebbles along with the foraged food.

The pieces of grit in the gizzards of all hens examined were well rounded at the edges and were somewhat smaller in the hens in captivity than in the controls.

Under the circumstances, it may not be fair to use the weight of grit in the controls as normal for the hens in confinement. The amount found in the hens of lots 3 and 4, which received both calcareous and siliceous materials *ad libitum,* may be the better basis of comparison. The average weight per hen in these two lots, taken together, is 11.3 grams. The average weights of grit for lots 5 and 6 are 39 per cent and 47 per cent of this amount, respectively, whereas lots 2 and 1 had about 26 per cent and 10 per cent more, respectively, than this assumed normal.

The hens in lot 2 took from the hoppers considerably more grit during their eight months of confinement than did those in lots 3 and 4; obviously this was caused by their desire and efforts to obtain calcium.

The quantity of limestone taken from the hoppers by lot 5 was about the same as the quantity of rock phosphate taken by lot 6.

The quantity of grit taken by lot 3 is about the same as the quantity of oyster shell taken. This would signify the inability of the hens to distinguish between the two materials which were

placed before them in adjoining hoppers. This is shown to hold true in the case of lot 4, also, which took about the same quantity of grit as of limestone.

The hens of lot 4 took from the hoppers only about half as much grit and limestone as the hens of lot 3 took of grit and shell; a striking difference for which no explanation occurs to us.

It is proper to note that the limestone and phosphate rock consumed by lots 5 and 6 in eight months may have supplied 17 grams and 12 grams of grit, respectively, according to the experiment described on page 19.

Part IV.

TABULATED DATA

For convenience of reference and for the purpose of presenting the chemical analyses adequately, the principal data obtained in the experiment described in the foregoing pages have been arranged in the following tables.

Table 14 gives the number of eggs laid each month by each hen. The letter "D," followed by a date, shows when a hen died.

Table 15 shows how the average egg production was computed from the data in table 14, after excluding all hens that laid not more than 5 eggs during the time they were in the experiment. If a hen died, she was counted N/30 of a hen for the month in which she died, "N" being the number of days she lived in that month. Strictly speaking, the "months" were 30 day periods.

Tables 16 to 37, inclusive, contain results of the laboratory work done on the eggs. The first three eggs laid by each hen in each lot, each month, or all she laid, if fewer than three, were taken as the sample for analysis. Bearing this in mind, it is possible to ascertain by consulting Table 16 how many hens, eggs and analyses each monthly average represents. For example, the first number in Table 16, 40.18, is the average weight of one egg, computed from the weight of 14 eggs from 7 hens. Simi-

larly, the first number in Table 17, 0.03, is the average weight of calcium oxid per egg, computed from 7 independent determinations of calcium in the contents of 14 eggs from 7 hens. The lowest numbers averaged were in July, when the samples from lots 1 and 3, respectively, consisted of 6 eggs from two hens, and the samples from lot 5 consisted of 7 eggs from 3 hens. We desire to call attention to the considerable number of independent determinations represented by each monthly average, because this adds weight to the averages. The size of the tables would be increased unduly, however, if all determinations represented in each average were stated.

Tables 37 to 40, inclusive, relate to the analyses of the leg bones and carcasses. They are self-explanatory.

Table 41 gives the average amounts of feeds and supplements consumed, expressed as pounds per hen. The same system of computation was used as in table 15.

Table 42 gives the monthly weights, in grams, of the hens that lived thru the experiment. It was not thought necessary to include the weights of hens that died before the close of the experiment.

Table 14—Individual Egg and Mortality Record

Lot 1. No Minerals.

Hen No.	Dec. 1920	Jan. 1921	Feb.	Mar.	Apr.	May	June	July	Total
1	6	7	2	8	5	1	1	D July 3	30
2	1	1	D Jan. 27	....	—	....	....	....	2
3	6	5	5	3	1	D Apr. 19	....	....	20
4	11	13	10	6	6	D Apr. 29	....	....	46
5	....	1	....	....	....	....	....	D July 29	1
6	1	2	3	4	3	2	4	9	28
7	2	1	1	2	1	....	....	8	15
8	....	....	....	1	1	1	1	D July 14	5
9	1	....	4	....	....	D Apr. 27	....	....	5
10	....	2	....	....	D Mar. 11	....	....	....	2
Floor	3	....	....	....	....	....	....	....	3
Total	31	32	26	24	17	4	6	17	157

Lot 2. Granite Grit.

1	6	7	11	13	13	9	2	D June 18	61
2	5	2	10	16	5	1	7	3	49
3	5	4	6	9	9	5	4	6	48
4	....	6	6	11	7	5	4	6	45
5	6	1	3	5	5	3	1	....	24
6	5	6	3	9	5	D Apr. 22	....	....	28
7	....	....	1	3	2	....	....	2	8
8	....	D Dec. 13	....	....	....	....	....	....	....
9	....	6	1	5	4	4	7	6	33
10	....	3	3	4	2	....	D May 23	....	12
Floor	6	...	1	2	1	....	6	2	18
Total	33	35	45	77	53	27	31	25	326

Lot 3. Grit and Oystershell.

Hen No.	Dec. 1920	Jan. 1921	Feb.	Mar.	Apr.	May	June	July	Total
1	8	4	10	17	11	14	5	9	78
2	3	5	1	7	8	4	3	....	31
3	11	7	11	7	....	D Apr. 14	....	....	36
4	3	7	4	5	5	2	D May 27	....	26
5	4	5	....	D Feb. 1	....	....	....	....	9
6	....	....	10	12	10	5	D May 26	....	37
7	....	....	....	D Feb. 1	....	....	....	....	....
8	....	1	9	8	19	6	16	17	76
9	....	3	....	6	9	2	4	....	24
10	....	3	1	4	6	8	....	D June 4	22
Floor	4	1	7	5	....	7	1	....	25
Total	33	36	53	71	68	48	29	26	364

Lot 4. Grit and Limestone.

1	12	9	12	7	15	7	10	7	79
2	12	15	16	10	18	5	5	....	81
3	....	2	....	....	....	D Apr. 17	....	....	2
4	....	8	5	3	18	7	D May 31	....	41
5	....	5	16	4	20	10	6	2	63
6	1	....	5	1	3	6	1	....	17
7	....	6	9	7	13	5	6	8	54
8	6	5	11	3	6	3	7	4	45
9	....	....	2	1	10	6	4	D July 6	23
10	....	....	3	....	9	8	7	....	27
Floor	....	13	8	18	7	1	8	10	65
Total	31	63	87	54	119	58	54	31	497

Table 14—Individual Egg and Mortality Record—Concluded.

Lot 5. Limestone

Hen No.	Dec. 1920	Jan. 1921	Feb.	Mar.	Apr.	May	June	July	Total
1	3	7	8	3	13	4	2	....	40
2	....	....	D Jan. 18	....	....	....	....	....	....
3	8	6	5	10	12	....	D May 8	....	41
4	3	7	....	3	12	5	....	D June 6	30
5	6	11	10	4	7	10	13	5	66
6	9	14	9	10	8	9	4	D June 16	63
7	4	5	2	9	8	1	8	3	40
8	....	10	15	13	10	7	D June 25	....	55
9	2	D Dec. 26	....	....	....	....	....	....	2
10	....	3	....	5	9	12	7	1	37
Floor	4	3	6	26	20	6	9	....	74
Total	39	66	55	83	99	54	43	9	448

Lot 6. Rock Phosphate

1	1	2	4	7	6	4	4	1	29
2	2	....	....	D Feb. 16	....	....	....	....	2
3	1	5	....	5	3	....	1	....	15
4	....	2	3	....	....	....	....	D June 24	5
5	....	....	....	....	4	2	5	3	14
6	....	3	4	4	2	1	4	8	26
7	4	5	1	3	3	....	....	2	18
8	....	3	....	D Feb. 15	....	....	....	....	3
9	2	1	D Jan. 21	....	....	....	....	....	3
10	....	1	3	....	D Mar. 10	....	....	....	4
Floor	1	1	....	2	....	1	....	1	6
Total	11	23	15	21	18	8	14	15	125
No. dead	2	3	4	2	6	5	6	4	
Total in 4 months				11				21	

Table 15—Average Egg Production of Hens Laying Over 5 Eggs

Month	Lot 1, No Minerals			Lot 2, Grit			Lot 3, Grit, Shell		
	No. of Hens	No. of Eggs	Eggs Per Hen	No. of Hens	No. of Eggs	Eggs Per Hen	No. of Hens	No. of Eggs	Eggs Per Hen
Dec., 1920	5.0*	29	5.8	9.0	33	3.7	9	33	3.7
Jan., 1921	5.0	28	5.6	9.0	35	3.9	9	36	4.0
Feb., 1921	5.0	21	4.2	9.0	45	5.0	8	53	6.6
Mar., 1921	5.0	23	4.6	9.0	77	8.6	8	71	8.9
Apr., 1921	4.5	16	3.6	8.7	53	6.1	7.5	68	9.1
May, 1921	3.0	3	1.0	7.7	27	3.5	6.7	48	7.3
June, 1921	3.0	5	1.7	6.6	31	4.7	4.1	29	7.1
July, 1921	2.1	17	8.0	6.0	25	4.2	4.0	26	6.5
Total		142	34.5		326	39.7		364	53.2
No. hens at close of expt.	2			6			4		

*Of the ten hens placed in Lot 1, five failed to lay more than 5 eggs.

Month	Lot 4, Grit Limestone			Lot 5, Limestone			Lot 6, Rock Phosphate		
	No. of Hens	No. of Eggs	Eggs Per Hen	No. of Hens	No. of Eggs	Eggs Per Hen	No. of Hens	No. of Eggs	Eggs Per Hen
Dec., 1920	9	31	3.4	8	37	4.6	5	7	1.4
Jan., 1921	9	61	6.8	8	66	8.3	5	16	3.2
Feb., 1921	9	87	9.7	8	55	6.9	5	9	1.8
Mar., 1921	9	54	6.0	8	83	10.4	5	21	4.2
Apr., 1921	9	119	13.2	8	99	12.4	5	18	3.6
May, 1921	9	58	6.4	7	54	7.7	5	8	1.6
June, 1921	8	54	6.8	4.7	43	9.2	5	14	2.8
July, 1921	7.2	31	4.3	4	9	2.3	5	15	3.0
Total		495	56.6		446	61.8		108	21.6
No. hens at close of expt.	7			4			5		

Table 16—Average Weight of the Contents, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	40.18	39.47	43.54	41.90	38.26	45.03	41.55	43.56
2	42.00	44.07	46.45	43.56	40.49	43.96	42.80	42.79
3	38.99	42.78	46.75	46.90	38.69	41.53	38.97	44.27
4	40.66	45.25	46.45	42.90	46.46	43.66	41.43	40.06
5	39.72	41.76	44.88	44.52	45.69	42.04	42.80	41.47
6	39.83	39.50	42.95	41.71	41.68	37.36	41.30	40.55

Table 17—Average Weight of CaO in the Contents, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.030	.025	.028	.028	.025	.035	.031	.028
2	.033	.029	.034	.029	.029	.033	.032	.030
3	.032	.031	.032	.028	.034	.032	.031	.037
4	.037	.035	.035	.034	.036	.032	.031	.032
5	.031	.027	.033	.034	.035	.031	.032	.034
6	.036	.030	.035	.034	.032	.031	.031	.030

Table 18—Average Weight of MgO in the Contents, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.010	.009	.009	.009	.008	.008	.009	.009
2	.011	.010	.009	.010	.009	.009	.009	.009
3	.010	.008	.010	.009	.009	.008	.008	.008
4	.011	.009	.010	.008	.010	.011	.009	.008
5	.010	.009	.009	.009	.009	.009	.009	.008
6	.011	.009	.009	.010	.010	.010	.010	.010

Table 19—Average Weight of P_2O_5 in the Contents, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.173	.175	.196	.178	.172	.206	.204	.189
2	.203	.173	.219	.208	.194	.209	.208	.216
3	.194	.177	.223	.227	.219	.207	.209	.228
4	.202	.189	.228	.212	.234	.222	.210	.205
5	.200	.195	.215	.219	.225	.211	.226	.227
6	.200	.196	.197	.195	.190	.196	.203	.194

Table 20—Average Percentage of CaO in the Contents

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.074	.063	.064	.067	.065	.078	.075	.064
2	.078	.066	.073	.066	.072	.075	.075	.070
3	.082	.070	.071	.060	.087	.077	.079	.084
4	.091	.077	.075	.079	.077	.073	.075	.080
5	.078	.064	.073	.076	.076	.074	.073	.082
6	.090	.076	.081	.081	.077	.083	.075	.074

Table 21—Average Percentage of MgO in the Contents

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.025	.023	.021	.021	.021	.018	.022	.021
2	.026	.023	.020	.023	.023	.021	.021	.021
3	.025	.019	.021	.019	.023	.019	.020	.018
4	.027	.020	.021	.019	.022	.025	.022	.020
5	.025	.021	.020	.020	.020	.021	.022	.019
6	.027	.023	.021	.024	.024	.027	.024	.024

Table 22—Average Percentage of P_2O_5 in the Contents

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.43	.44	.45	.43	.45	.46	.49	.43
2	.48	.39	.47	.47	.48	.48	.49	.50
3	.50	.42	.48	.48	.57	.49	.53	.52
4	.50	.42	.49	.49	.50	.51	.51	.51
5	.50	.46	.48	.49	.49	.50	.52	.55
6	.50	.49	.46	.47	.45	.52	.49	.48

Table 23—Average Weight of CO_2-free Shell Ash, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	2.26	1.94	2.21	1.66	1.59	1.69	1.63	1.77
2	2.35	2.17	2.29	1.96	1.75	1.66	1.75	1.93
3	2.43	2.61	2.93	2.51	2.56	2.13	2.17	2.27
4	2.65	2.77	2.76	2.64	2.51	2.15	1.76	2.15
5	2.39	2.60	2.90	2.70	2.70	2.47	2.24	2.33
6	1.79	1.81	1.87	1.93	1.79	1.97	1.76	1.62

Table 24—Average Weight of CaO in Shell, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	2.183	1.888	2.160	1.613	1.553	1.655	1.594	1.726
2	2.284	2.109	2.235	1.919	1.710	1.610	1.707	1.885
3	2.364	2.540	2.860	2.452	2.509	2.088	2.124	2.216
4	2.572	2.709	2.701	2.584	2.438	2.095	1.715	2.098
5	2.340	2.524	2.833	2,624	2.650	2.394	2.190	2.280
6	1.739	1.769	1.829	1.890	1.748	1.923	1.722	1.584

Table 25—Average Weight of MgO in the Shell, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.034	.027	.031	.026	.024	.023	.022	.024
2	.034	.027	.034	.030	.027	.027	.025	.028
3	.030	.031	.037	.032	.033	.029	.027	.033
4	.034	.034	.036	.034	.035	.034	.028	.029
5	.033	.032	.038	.035	.037	.035	.031	.032
6	.027	.027	.026	.029	.029	.036	.030	.026

Table 26—Average Weight of P_2O_5 in the Shell, Expressed as Grams per Egg

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.016	.014	.014	.011	.012	.012	.011	.015
2	.017	.017	.015	.011	.011	.009	.011	.011
3	.013	.017	.013	.013	.015	.012	.014	.016
4	.015	.017	.016	.014	.016	.014	.011	.012
5	.016	.017	.015	.016	.016	.015	.014	.016
6	.019	.008	.008	.008	.009	.010	.006	.009

Table 27—Average Percentage of CaO in the CO_2-free Ash of the Shell

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	96.59	97.32	97.74	97.17	97.68	97.93	97.80	97.52
2	97.19	97.19	97.60	97.91	97.71	96.99	97.54	97.67
3	97.29	97.32	97.61	97.69	98.01	98.03	97.88	97.63
4	97.06	97.80	97.86	97.88	97.14	97.45	97.44	97.58
5	97.91	97.08	97.69	97.19	98.15	96.93	97.77	97.85
6	97.15	97.74	97.81	97.93	97.66	97.61	97.84	97.78

Table 28—Average Percentage of MgO in the CO_2-free Ash of the Shell

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	1.50	1.39	1.40	1.57	1.51	1.36	1.35	1.36
2	1.45	1.24	1.49	1.53	1.54	1.63	1.43	1.45
3	1.25	1.19	1.26	1.27	1.29	1.36	1.24	1.45
4	1.28	1.23	1.30	1.29	1.39	1.58	1.59	1.35
5	1.38	1.23	1.31	1.30	1.37	1.43	1.38	1.37
6	1.51	1.49	1.39	1.50	1.62	1.83	1.70	1.60

Table 29—Average Percentage of P_2O_5 in the CO_2-free Ash of the Shell

ot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.71	.72	.63	.66	.76	.71	.68	.85
2	.72	.73	.66	.56	.63	.54	.63	.57
3	.54	.65	.44	.52	.59	.57	.65	.71
4	.57	.61	.58	.53	.64	.65	.63	.56
5	.67	.65	.52	.59	.59	.61	.63	.72
6	.56	.43	.43	.41	.50	.51	.34	.55

Table 30—Average Weight of one Egg, Grams

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	45.59	44.31	48.68	46.15	42.04	49.23	45.54	47.98
2	47.88	48.85	51.78	48.14	44.66	48.04	46.91	47.32
3	44.67	48.73	53.27	53.16	44.30	46.51	43.88	49.92
4	46.79	51.37	52.60	48.47	51.94	48.49	45.65	44.90
5	45.43	47.55	51.19	50.45	51.60	47.37	47.75	46.47
6	44.56	43.84	47.38	46.11	45.93	41.80	45.60	44.54

Table 31—Average Weight of CaO in the Whole Egg, Grams

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	2.213	1.913	2.188	1.641	1.578	1.690	1.625	1.754
2	2.317	2.138	2.269	1.948	1.739	1.643	1.739	1.915
3	2.396	2.571	2.893	2.480	2.543	2.120	2.155	2.253
4	2.609	2.744	2.736	2.618	2.474	2.127	1.746	2.132
5	2.371	2.551	2.866	2.658	2.685	2.425	2.222	2.314
6	1.775	1.799	1.864	1.924	1.780	1.954	1.753	1.614

Table 32—Average Weight of MgO in the Whole Egg, Grams

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.044	.036	.040	.035	.032	.031	.031	.033
2	.045	.037	.043	.040	.036	.036	.034	.037
3	.040	.039	.047	.041	.042	.037	.035	.041
4	.045	.043	.046	.042	.045	.045	.037	.037
5	.043	.041	.047	.044	.046	.044	.040	.040
6	.038	.036	.035	.039	.039	.046	.040	.036

Table 33—Average Weight of P_2O_5 in the Whole Egg, Grams

Lot No.	Dec.	Jan.	Feb	Mar.	Apr.	May	June	July
1	.189	.179	.210	.189	.184	.218	.215	.204
2	.220	.190	.234	.219	.205	.218	.219	.227
3	.207	.194	.233	.240	.234	.219	.223	.244
4	.217	.206	.244	.226	.250	.236	.221	.217
5	.216	.212	.230	.235	.241	.226	.240	.243
6	.210	.204	.205	.203	.199	.206	.209	.203

Table 34—Average Percentage of CaO in the Whole Egg.

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	4.86	4.32	4.50	3.56	3.75	3.43	3.57	3.66
2	4.84	4.38	4.38	4.05	3.89	3.42	3.71	4.05
3	5.36	5.26	5.43	4.67	5.74	4.56	4.91	4.51
4	5.58	5.34	5.20	5.40	4.76	4.39	3.83	4.75
5	5.22	5.36	5.60	5.27	5.20	5.12	4.65	4.98
6	4.00	4.10	3.93	4.17	3.88	4.67	3.84	3.62

Table 35—Average Percentage of MgO in the Whole Egg.

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.096	.081	.082	.076	.076	.063	.068	.069
2	.094	.076	.083	.083	.081	.075	.073	.078
3	.089	.080	.088	.077	.095	.080	.080	.091
4	.095	.085	.087	.087	.086	.093	.081	.082
5	.094	.086	.092	.087	.091	.093	.084	.086
6	.086	.082	.074	.085	.089	.090	.088	.081

Table 36—Average Percentage of P_2O_5 in the Whole Egg.

Lot No.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.42	.40	.43	.41	.44	.44	.47	.43
2	.46	.39	.45	.46	.46	.45	.47	.48
3	.47	.40	.44	.45	.53	.47	.51	.50
4	.47	.40	.46	.47	.48	.49	.48	.48
5	.47	.44	.45	.47	.47	.48	.50	.52
6	.47	.46	.43	.44	.43	.50	.46	.46

Table 37—Weight of the Four Leg Bones and of the Mineral Content Thereof, expressed in Grams

Lot No.	Hen No.	Four Leg Bones		CO_2-free Ash in 4 Leg Bones	CaO in 4 Leg Bones	MgO in 4 Leg Bones	P_2O_5 in 4 Leg Bones
		Fresh	Dried at 120° C.				
1st control	A	23.20	14.72	5.56	3.088	.073	2.297
	B	21.49	12.98	5.70	3.092	.078	2.385
	Average	22.34	13.85	5.63	3.090	.075	2.341
1	5	27.06	14.62	7.60	4.152	.103	3.123
	6	32.04	18.22	8.46	4.587	.093	3.483
	7	31.98	17.47	7.85	4.258	.096	3.217
	Average	30.36	16.77	7.97	4.332	.098	3.274
2	7	32.67	18.48	9.05	4.924	.104	3.694
	9	27.83	17.18	7.37	3.942	.074	2.996
	2	33.57	21.12	9.78	5.390	.115	3.981
	3	34.01	19.32	8.95	4.898	.104	3.673
	4	33.59	19.86	8.49	4.596	.105	3.470
	5	30.02	18.57	9.16	5.008	.121	3.676
	Average	31.95	19.09	8.80	4.793	.104	3.582
3	9	31.22	21.30	12.32	6.741	.148	5.013
	1	30.24	20.88	8.94	4.908	.108	3.622
	8	32.45	21.04	10.51	5.720	.118	4.229
	Average	31.30	21.07	10.59	5.789	.125	4.288
4	1	27.73	21.12	9.26	5.115	.102	3.802
	6	25.79	20.23	9.86	5.504	.122	4.047
	10	28.37	21.30	8.23	4.595	.093	3.410
	7	38.51	23.69	12.72	7.010	.158	5.178
	8	33.23	19.95	10.80	5.835	.138	4.424
	Average	30.73	21.26	10.18	5.612	.123	4.172
5	1	28.50	18.84	10.01	5.451	.112	4.061
	5	29.85	19.63	11.03	6.049	.150	4.488
	7	36.63	25.40	14.03	7.786	.146	5.730
	10	27.19	15.58	7.69	4.253	.083	3.181
	Average	30.54	19.86	10.69	5.885	.123	4.365
6	3	29.67	18.81	9.96	5.441	.099	4.040
	6	32.76	19.67	10.96	5.944	.124	4.472
	1	37.69	26.24	13.08	7.227	.173	5.300
	5	36.21	24.14	13.44	7.442	.180	5.413
	7	29.25	16.88	8.58	4.773	.109	3.486
	Average	33.12	21.15	11.20	6.165	.137	4.542
2nd control	C	36.98	23.30	11.94	6.557	.143	4.880

Table 38—Average Percentages of CO_2-free Ash in the Four Leg Bones and of Mineral Substances in the Ash

Lot No.	Hen No.	CO_2-free Ash		CaO in the Ash	MgO in the Ash	P_2O_5 in the Ash
		Fresh	Dried at 120° C.			
1st control	A	23.97	37.77	55.53	1.31	41.32
	B	26.52	43.91	54.24	1.37	41.85
	Average	25.24	40.84	54.88	1.34	41.58
1	5	28.09	51.98	54.64	1.36	41.10
	6	26.40	46.43	54.22	1.10	41.17
	7	24.55	44.94	54.24	1.24	40.98
	Average	26.35	47.78	54.33	1.23	41.08
2	7	27.70	48.97	54.41	1.15	40.82
	9	26.48	42.90	53.49	1.00	40.65
	2	29.13	46.31	55.11	1.18	40.71
	3	26.33	46.32	54.73	1.16	41.04
	4	25.28	42.75	54.14	1.24	40.87
	5	30.51	49.33	54.67	1.32	40.13
	Average	27.57	46.10	54.44	1.18	40.70
3	9	39.46	57.84	54.72	1.20	40.71
	1	29.57	42.72	54.90	1.21	40.51
	8	32.39	49.96	54.42	1.12	40.24
	Average	33.81	50.17	54.68	1.18	40.49
4	1	29.79	43.89	55.24	1.10	41.06
	6	38.23	48.74	55.82	1.24	41.04
	10	29.01	38.64	55.83	1.13	41.43
	7	33.03	53.70	55.11	1.24	40.71
	8	32.50	54.14	54.03	1.28	40.96
	Average	32.51	47.82	55.21	1.19	41.04
5	1	35.12	53.14	54.46	1.12	40.57
	5	36.95	56.19	54.84	1.36	40.68
	7	38.30	55.24	55.49	1.04	40.84
	10	28.28	49.35	55.31	1.08	41.37
	Average	34.66	53.48	55.02	1.15	40.87
6	3	33.57	52.95	54.63	1.00	40.56
	6	33.46	55.72	54.24	1.13	40.80
	1	34.70	49.85	55.25	1.32	40.52
	5	37.12	55.68	55.37	1.34	40.30
	7	29.33	50.83	55.63	1.27	40.63
	Average	33.64	53.01	55.02	1.21	40.56
2nd control	C	32.29	51.24	54.92	1.20	40.87

Table 39—Weights of Carcasses and of Mineral Substances Estimated Therein, Grams

Lot No.	Hen No,	Hen as Received	Carcass as Analyzed	CO_2-free Ash in Carcass as Analyzed	CaO in Carcass as Analyzed	MgO in Carcass as Analyzed	P_2O_5 in Carcass as Analyzed
1st control	A	819	480	17.85	7.663	.350	7.793
	B	862	490	15.65	6.423	.318	6.810
	Average	840	485	16.75	7.043	.334	7.301
1	5	1100	689	24.20	10.394	.445	10.657
	6	1262	719	24.05	9.964	.445	10.370
	7	1247	673	22.60	9.734	.434	10.023
	Average	1203	694	23.62	10.031	.441	10.350
2	7	1197	654	21.54	9.103	.362	9.266
	9	1432	894	23.14	9.411	.414	10.138
	2	1295	778	27.04	11.910	.384	11.508
	3	1650	1030	27.60	11.216	.497	11.374
	4	1391	821	27.63	11.298	.542	12.179
	5	1383	884	26.55	11.072	.462	11.386
	Average	1392	844	25.58	10.668	.443	10.975
3	9	1007	629	27.41	13.025	.469	11.484
	1	1287	816	24.78	11.383	.406	10.758
	8	1342	829	30.61	12.136	.432	11.916
	Average	1212	758	27.60	12.185	.436	11.389
4	1	1247	749	24.11	10.519	lost	10.528
	6	1196	735	24.93	10.827	.451	10.636
	10	1194	757	24.23	10.417	.434	10.729
	7	1518	879	31.72	15.162	.463	13.266
	8	1452	900	32.62	15.458	.535	13.521
	Average	1321	804	27.32	12.473	.466	11.736
5	1	910	546	22.73	10.561	.389	9.672
	5	1245	811	28.37	13.069	.431	12.176
	7	1374	872	31.06	14.480	.497	13.203
	10	1022	638	22.49	10.647	.373	9.313
	Average	1138	717	26.16	12.184	.422	11.091
6	3	1409	851	26.91	12.472	.436	11.584
	6	1371	851	25.07	12.256	.406	10.773
	1	1416	827	30.05	13.587	.411	12.729
	5	1564	996	38.69	18.636	.677	16.060
	7	1141	676	23.91	10.379	.435	10.269
	Average	1380	840	28.93	13.466	.473	12.283
2nd control	C	1499	963	28.17	12.246	.507	12.127

Table 40—Percentage of CO_2-free Ash in the Carcass as Analyzed and of Mineral Substances in the CO_2-free Ash

Lot No.	Hen No.	Ash in the Carcass	CaO in the Ash	MgO in the Ash	P_2O_5 in the Ash
1st controls	A	3.72	42.93	1.96	43.66
	B	3.19	41.04	2.03	43.51
	Average	3.45	41.98	1.99	43.58
1	5	3.51	42.95	1.84	44.03
	6	3.35	41.43	1.85	43.13
	7	3.36	43.07	1.92	44.35
	Average	3.41	42.48	1.87	43.84
2	7	3.29	42.26	1.68	43.04
	9	2.59	40.67	1.79	43.81
	2	3.48	44.05	1.42	42.56
	3	2.68	40.64	1.80	41.21
	4	3.37	40.89	1.96	44.07
	5	3.00	41.70	1.74	42.89
	Average	3.07	41.70	1.73	42.93
3	9	4.36	47.52	1.71	41.90
	1	3.04	45.94	1.64	43.43
	8	3.69	39.65	1.41	38.93
	Average	3.69	44.37	1.58	41.42
4	1	3.22	43.63	.....	43.67
	6	3.39	43.43	1.81	42.66
	10	3.20	43.00	1.79	44.28
	7	3.61	47.80	1.46	41.82
	8	3.62	47.39	1.64	41.45
	Average	3.41	45.05	1.62	42.78
5	1	4.16	46.45	1.71	42.55
	5	3.50	46.06	1.52	42.92
	7	3.56	46.62	1.60	42.51
	10	3.54	47.34	1.66	41.41
	Average	3.69	46.62	1.62	42.35
6	3	3.16	46.35	1.62	43.05
	6	2.95	48.89	1.62	42.97
	1	3.63	45.23	1.37	42.36
	5	3.88	48.17	1.75	41.51
	7	3.54	43.41	1.82	42.95
	Average	3.43	46.41	1.64	42.57
2nd control	C	2.93	43.47	1.80	43.05

Table 41—Mineral Supplements Consumed. Pounds per Hen*

Month	Lot 2	Lot 3		Lot 4		Lot 5	Lot 6
	Grit	Grit	Shell	Grit	Lime-stone	Lime-stone	Phos-phate
Dec., 1920	1.0	0.3	0.4	0.4	0.1	0.4	0.5
Jan., 1921	0.8	0.2	0.6	0.1	0.4	0.7	0.5
Feb., 1921	0.6	0.4	0.2	0.5	0.5	0.5	0.4
Mar., 1921	0.6	0.4	0.5	0.4	0.2	0.4	0.6
Apr., 1921	0.3	0.4	0.9	0.6	0.3	0.3	0.4
May, 1921	1.3	0.9	0.8	0.3	0.3	0.3	0.8
June, 1921	2.3	2.6	1.5	0.8	0.8	0.9	0.6
July, 1921	3.3	1.2	1.6	0.2	0.3	1.0	0.2
Total	10.2	6.4	6.5	3.3	2.9	4.5	4.0

*The figures represent the quantities of the different materials taken from the hoppers by the hens; an undetermined part of this was not swallowed, but dropt upon the floor.

Table 42—Weights of the Hens that Lived Thru the Experiment, Grams

Lot No.	Hen No.	Dec. 1	Dec. 31	Jan. 29	Feb. 28	Mar. 30	Apr. 29	May 29	June 29	July 29
1	6	1080	1309	1450	1370	1298	1284	1250	1245	1253
	7	1069	1535	1327	1432	1435	1350	1340	1280	1311
Average		1075	1422	1389	1401	1367	1317	1295	1263	1282
							Increase 207—19 per cent.			
2	2	1157	1350	1742	1678	1330	1152	1350	1330	1275
	3	1497	1780	1751	1846	1350	1587	1560	1620	1590
	4	1225	1640	1504	1623	1641	1453	1365	1336	1452
	5	1199	1250	1350	1493	1495	1351	1250	1251	1381
	7	1027	1165	987	1287	1219	1149	970	1197	1257
	9	1040	1452	1536	1450	1495	1279	1425	1475	1453
Average		1191	1439	1475	1563	1422	1329	1320	1368	1406
							Increase 315—26 per cent			
3	1	1407	1720	1710	1629	1425	1529	1347	1290	1260
	2	1107	1355	1360	1261	1180	1039	980	820	642
	8	980	1435	1488	1265	1390	1290	1450	1362	1292
	9	935	1347	1090	1226	1213	1112	1086	1121	1109
Average		1107	1463	1412	1345	1302	1243	1216	1148	1076
								Loss 31—3 per cent		
4	1	1275	1595	1506	1539	1523	1339	1342	1286	1252
	2	1272	1420	1431	1383	1474	1215	1380	1439	1100
	5	1215	1555	1827	1582	1860	1666	1535	1489	1037
	6	1100	1405	1743	1726	1736	1710	1530	1520	1214
	7	1145	1705	1820	1840	1758	1379	1449	1328	1470
	8	1145	1530	1686	1440	1550	1356	1381	1219	1490
	10	902	985	1236	1385	1513	1329	1202	1091	1210
Average		1151	1457	1607	1557	1631	1428	1403	1339	1253
							Increase 102—9 per cent.			
5	1	1112	1350	1432	1391	1372	1015	950	841	1092
	5	1065	1365	1510	1529	1472	1305	1386	1241	1403
	7	1112	1340	1280	1402	1361	1229	1370	1241	1460
	10	907	1120	1180	1059	1197	1037	1040	1029	1050
Average		1049	1294	1351	1345	1351	1147	1187	1189	1251
							Increase 202—20 per cent.			
6	1	1325	1684	1480	1621	1459	1442	1525	1505	1529
	3	1220	1480	1480	1451	1374	1415	1480	1391	1503
	5	1205	1364	1040	986	1590	1532	1655	1555	1585
	6	1397	1574	1678	1795	1605	1619	1742	1780	1708
	7	1060	1185	1280	1341	1300	1285	1270	1191	1209
Average		1241	1457	1392	1439	1466	1459	1534	1484	1507
							Increase 266—21 per cent.			